IEEE P802.15
Wireless Personal Area Networks

Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)	
Title	**TG3 Interim Meeting Working Document**	
Date Submitted	[9 July, 2001]	
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Re:	[]	
Abstract	[This document is contains the issues and resolutions developed by the PHY subcommittee at its interim meeting..]	
Purpose	[To provide a record of the resolutions of the PHY subcommittee.]	
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1. Goals

1) **RESOLVED:** Generate words to define CCA - Gilb 6/14
2) **RESOLVED:** Generate words to define IFS'es and slots - Gilb, 6/14
3) **RESOLVED:** Generate words to define LQI (RSSI and MSE) - Karagouz, 6/14
4) **RESOLVED (needs wording):** Determine header coding and generate definition - Karagouz, 6/28
5) **RESOLVED:** Solve QPSK/OQPSK, provide suggested ammendment. - Gilb/Karagouz/Ling, 6/28
6) **RESOLVED:** Symbol clock synchronization - Ling/Holt, 6/14
   - Can we provide optional capability
7) **RESOLVED:** Review jamming margin numbers.- Chandra, 6/14
8) **RESOLVED:** Generate wording and picture for data whitener, determine seed source. - Karagouz, 6/14
9) **RESOLVED:** EVM measurement wording - Holt
10) **RESOLVED:** Review PLME commands and PHY PIB, resolve all problems. - Gilb/Roberts, 6/28
11) **RESOLVED:** Resolve any new MAC/PHY issues. - Gilb, 6/28
12) **RESOLVED:** Define or remove PHY service field. - Gilb, 6/28
13) **RESOLVED (needs wording):** Resolve possible lower speed (e.g. 11 Mb/s modes) and how to handle them. - Karagouz, 6/28
14) **RESOLVED:** Change frequency for lowest channel? Do we violate FCC 15.249 or do we go to the new 15.247? - Gilb, 6/28
15) **RESOLVED:** Do we add transmit power control? How is that implemented? Is it optional or mandatory? - Karagouz, 6/28
16) **RESOLVED:** Base rate, IFS, slots and other words - Gilb, 6/28

2. Agenda

Thursday, June 28, 2001

8:00 am	Call meeting to order
8:01 am	Approve/modify agenda
8:05 am	Determine dinner location
9:00 am	Work on goals in the order listed above
10:00 am	Recess for break
10:20 am	Meeting called to order
10:21 am	Continue work
12:00 pm	Recess for lunch
1:00 pm	Meeting called to order
1:01 pm	Continue work
3:30 pm	Recess for break
3:40 pm	Meeting called to order
3:41 pm	Continue work
6:00 pm	Recess for dinner

Friday, June 29, 2001

8:00 am	Meeting called to order
8:01 am	Continue work
10:00 am	Recess for break
10:20 am	Meeting called to order
10:21 am	Continue work
12:00 pm	Recess for lunch

1:00 pm	Meeting called to order
1:01 pm	Continue work
3:00 pm	Adjourn meeting

3. Items to resolve

3.1 Generate words to define CCA

Suggested wording:

The receiver ~~in a 2.4 GHz PHY~~ provides the CCA capability by performing energy detection in the received signal bandwidth. The receiver CCA shall report a busy medium upon detecting energy above the energy detect (ED) threshold in a 16 symbol window in the current receive channel (xref channel section). The 16 symbol interval corresponds to the length of a single CAZAC sequency (xref) and is approximately 1.45 us based on the 11 Msymbol/s symbol rate. The ED threshold shall be equal to -70 dBm integrated over a 16 symbol interval.

Added to d0.5, section 11.6.5 (JPKG, 5 July 01, deleted words with strikethrough above).

3.2 Generate words to define IFS'es and slots

Suggested wording:

11.2.6.1 Interframe spacing

For a compliant 802.15.3 2.4 GHz PHY, the following parameters shall be used:

This is really a table
MAC duration Value
SIFS = aRXTXTurnaround (xref)
Slot = aCCADetectTime (xref, currently 15 us)

Ed Note: RIFS = SIFS+slot (this actually is in the MAC, we won't reference it here).

The other option is to note in the RX/TX turnaournd that this is equal to the SIFS and have the MACFD point to this section. The slot would then be defined as an extra paragraph in the CCA section with a similar link from the MACFD.

We adopted the table, it is in d0.5, 11.2.6.1 (JPKG, 5 July 01)

3.3 Generate words to define LQI (RSSI and MSE)

RSSI is defined as the power relative to the maximum receiver input power level (xref) in 8 steps of 8 dB with +/- 4 dB accuracy for each step. The range covered shall be a minimum of 40 dB. The steps shall be monotonic. This number is reported to the SME and MLME via the PHY-RXSTART.indication (xref).

The link quality indication (LQI) shall be reported for the TCM coded QAM modes using an SNR estimation. The SNR shall be measured at the decision point in the receiver. The receiver shall report the SNR as a 5 bit number that covers a range of 12 dB to 27.5 dB of SNR. The value 0x00000 shall correspond to less than or equal to 12 dB SNR and 0x11111 shall correspond to more than or equal to 27.5 dB SNR with equal steps in between. *This number is reported to the SME and MLME via the PHY-RXSTART.indication (xref).*

Added text to d0.5 11.6.6 and 11.6.7, added new text, shown above in italics, as well (JPKG, 5 July 01)

3.4 Determine header coding and generate definition

The header will be sent at the base rate, because it has significantly less bits (12-14 bytes), it will have a higher pobability of reception that the frame.

3.5 Solve QPSK/OQPSK, provide suggested ammendment.

The original goal was to use OQPSK to reduce the backoff requirement for the PA. The theoretical advantage is 3 dB. The apparent gain is 0.5 dB on PA backoff according to document 01225r0. This is likely due to the baseband data shaping.

The problem with OQPSK is that the CAZAC sequence does not work for channel estimation. The CAZAC sequence is the most efficient way to do channel estimation for the equalizer, which is required for the higher data rate modes.

Table 1—QPSK/OQPSK comparison

Criteria	QPSK	OQPSK
PA backoff	Worse	Better (0.5 dB)
Filter linearity	More stringent	Less stringent (?? dB)
Band limiting in the receiver	Less tolerant	More tolerant (?? dB)
Progression to QAM	Easy	More difficult, requires additional gates
Supports CAZAC	Yes	No, requires different synchronization
Equalization	OK	Offset of I and Q makes it very different from QAM and therefore more complex
Ease of implementation	Same for digital implementations	Same for digital implementations. Has some (~0.5 dB) advantage in non-coherent implementations.

Conclusion is that due to the desire to take advantage the CAZAC sequence and be easily integrated with QAM modes, the QPSK is the preferred alternative.

All references to OQPSK have been removed from the PHY clause in d0.5 (JPKG, 5 July 2001)

3.6 Symbol clock synchronization

Can we provide optional capability? No, if it is to be implemented, everyone must do it so a receiver can rely on it.

The analysis is that if both the symbol clock and the frequency generation are derived from the same cyrstal, then the frequency error can be estimated from the symbol timing and vice-versa. There should be no impact on typical designs, so this will be adopted as 11.5.6 (new section) titled Clock synchronization.

Added to d0.5 at interim meeting (JPKG, 28 June 2001)

3.7 Review jamming margin numbers.

Reviewed, removed TBD and left most recent numbers.

Modified at interim meeting (JPKG, 29 June 2001)

3.8 Generate wording and picture for data whitener, determine seed source.

Seed source is 2 bits in the PHY header. Use a 16 bit seed that is shifted by 0, 4, 8, or 12 bits based on the value of the 2 bits. The bits are incremented in a 2 bit rollover counter that is incremented for each packet that is sent by the PHY.

Text from submission by Karaoguz:

A side-stream scrambler is used to randomize the data payload to be transmitted. The polynomial, $g(D)$, for the pseudo random binary sequence (PRBS) generator shall be

$$g(D) = 1 + D^{14} + D^{15}$$

where D is a single bit delay element. By the given generator polynomial, the corresponding PRBS, x_n, is generated as

$$x_n = x_{n-14} \oplus x_{n-15}$$

where "" $\oplus$ "" denotes modulo-2 addition.

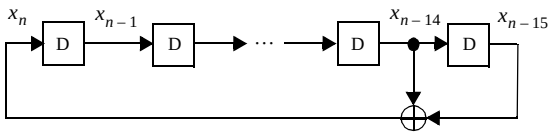

Figure 3.1—Realization of side-stream scrambler by linear feedback shift registers

Ed note: Add location where s_n is xor-ed with the x_n in the data stream.

The following sequence defines the initialization sequence, x_{init}

$$x_{\text{init}} = \left[x^i_{n-1}\ x^i_{n-2}\ x^i_{n-3}\ x^i_{n-4}\ x^i_{n-5}\ x^i_{n-6}\ x^i_{n-7}\ x^i_{n-8}\ x^i_{n-9}\ x^i_{n-10}\ x^i_{n-11}\ x^i_{n-12}\ x^i_{n-13}\ x^i_{n-14}\ x^i_{n-15} \right]$$

where x^i_{n-k} represents the binary initial value at the output of the k^{th} delay element.

The scrambled data bits, s_n, are obtained as follows

$$s_n = b_n \oplus x_n$$

where b_n represents the unscrambled data bits. The side-stream de-scrambler at the receiver must be initialized with the same initialization vector, x_{init}, used in the transmitter scrambler. The initialization vector is determined from the seed identifier contained in the PHY header of the received packet.

The 15 bit seed value chosen shall correspond to the seed identifier (xref PHY header) as shown in Tab. 3. 2.

Table 3.2—Scramber seed selection

Seed identifier	Seed value
00	0011 1111 1111 111
01	0111 1111 1111 111
10	1011 1111 1111 111
11	1111 1111 1111 111

The seed identifier value is set to 00 when the PHY is initialized and is incremented in a 2-bit rollover counter for each packet that is sent by the PHY. The value of the seed identifier that is used for the packet is sent in the PHY header (xref PHY header section.)

The 15-bit seed value is configured as follows. At the beginning of each burst, the register is cleared, the seed value is loaded, and the first scrambler bit is calculated. The first bit of data of the MAC header, is modulo-2 added with the first scrambler bit, followed by the rest of the bits in the MAC header and frame body.

Text from Karaoguz, above as modified in interim meeting, added to d0.5 (JPKG, 5 July 2001)

3.9 EVM measurement wording

Current wording is too strict on the transmitter. Add words to specify that the measurement is made with a carrier locked receiver that does symbol timing recovery and amplitude adjustment. Also relaxed the 64-QAM mode's SNR to 28 dB (2.6% EVM). Removed description of how to calculate EVM from SNR values since it was confusing. Compliance table now only has EVM % in the requirements

Corrections made at interim meeting (JPKG, 29 June 2001)

3.10 Review PLME commands and PHY PIB, resolve all problems.

Need to send email to Rick Roberts to verify that issues 31, 33-35, 38-41, 46-48, 50-51 have been resolved.

Email sent 29 June 2001, no response. J. Gilb will followup at Portland

Change table 54, RSSI to be 0 to PHYPIB_RSSI_max and define PHYPIB_RSSI_max in the 2.4 GHz PHY to be 7. Change table 54 to include the LQI, 0 to PHYPIB_LQI_max and define PHYPIB_LQI_max in the 2.4 GHz PHY PIB to be 31.

Add TX max power and TX power step size parameters to the PHY PIB

Change PHY CCA commands to:

PHY-CCA.start
PHY-CCA.end
PHY-CCA.request
PHY-CCA.confirm

Change the STATUS parameter to be associated with the PHY-CCA.confirm primitive.

Change PHY-RXNAP commands to:

PHY-RXEND.request
PHY-RXEND.confirm

Add PHY-PWRMGT.request and PHY-PWRMGT.confirm. The parameter for request is a PWRMGT-SETTING which is a 1 byte number that indicates one of the available PHY power management levels. The PHY responds with a confirm that is either NoError or UnsupportPwrMgtLevel.

6.8.4.16.2 should have as effect of receipt that the PHY stops its current reception.

Need to pass these to R. Roberts, J. Gilb will pass them on.

3.11 Resolve any new MAC/PHY issues.

No new issues.

3.12 Define or remove PHY service field.

The PHY service field is as follows (in order sent over the air):

— 2 bits seed indicator
— 3 bit rate indication
— 11 bit frame length in bytes

For a total length of 2 bytes.

Text added as sub-clause 11.4.3 in d0.5 (JPKG, 5 July 2001)

3.13 Resolve possible lower speed (e.g. 11 Mb/s modes) and how to handle them.

One proposal is to use an 11 Mb/s header and 11 Mb/s payload. The reason for a lower rate mode is to support

— larger range
— fall back mode for better link quality.

The suggestion is to use BPSK for the frame body only. The PHY preamble and the packet header remain the same as currently defined. The current wording will allow that.

The resolution is to include BPSK mode in the frame for 11 Mb/s

Added to tables throughout the clause 11, d0.5. Added a scaling factor for amplitude and two tail bits (01) for the BPSK mode. Also added RX sensitivity and blocking requirements by adding 3 dB. Still need bits to symbol mapping and possibly to add it to the constellation picture.

3.14 Change frequency for lowest channel? Do we violate FCC 15.249 or do we go to the new 15.247?

Note 1: It appears under the ARIB STD-T66 that the lowest channel would not meet the spurious requirement of 25 uW in 2387-2400 MHz band. Therefore we will make channel 1 in all channel plans optional depending on the regulatory region.

Upon further review, we note that 25 uW is pretty easy to meet, so channel 1 is fine.

Table 3—Comparison of 15.247+NPRM and 15.249

Criteria	15.247+NPRM	15.249
Availability	Real Soon Now™	now
Minimum channel separation (with 15 MHz BW)	3 MHz	1 MHz
Transmit power	125 mW (+21 dBm) (~ 2 W DC power for this level)	~ +8 dBm
World wide TX power limit	+10 dBm	~ +8 dBm
Implementation ease/cost	Easier TX filter, 8 MHz 30 dB point, 16 MHz 40 dB point, less gates, cheaper	baseline
Adjacent channel interference	Better, depending on PSD	baseline
Risk if NPRM not approved	Need to change channel programming only	baseline

Proposal is to move to the 15.247 + new NPRM regulations.

J. Gilb will add this proposed changes to be voted on.

3.15 Do we add transmit power control? How is that implemented? Is it optional or mandatory?

A compliant transmitter that is capable of transmitting more than 4 dBm shall be capable of reducing its power to less than 4 dBm in monotonic steps no smaller than 3 dB and no larger than 5 dB. The steps shall form a monotonically decreasing sequence. A compliant device shall have its maximum transmit power level and nominal power level step size indicated in its PHY PIB.

Need to make sure this is reflected in the PIB, text is added to d0.5, sub-clause 11.5.9 (JPKG, 5 July 2001)

3.16 Base rate, IFS, slots and other words

The SIFS and Slot are handled (hopefully) in the definitions of 3.2. To handle the base rate, propose adding wording to the end of 11.3 or adding an “11.3.1 Base rate” that says:

The base rate of the 802.15.3 2.4 GHz PHY shall be the 22 Mb/s, uncoded QPSK mode.

This definition is required to support the MAC frame format description and is a PHY dependent parameter.

Text added as sub-clause 11.3.1 in d0.5 (JPKG 5 July 2001)

4. New Items

4.1 Header SNR improvement

Propose that the header is sent QPSK to reduce the overhead, the header is still more likely to be recieved correctly since it is shorter than typical data packets. In a fading environment, the change in the path loss is easily more than 3 dB, the proposed gain in the header SNR. In an interference limited enviroment, increased probability of packet reception is more dependent on the time on the air.

Text added to d0.5 in sub-clause 11.4.2 (JPKG, 5 July 2001)

4.2 Differential encoding of QPSK mode

There was a discussion about differential encoding of the base mode. The consensus is to add differential encoding for the base rate mode only to allow simpler receiver implementations.

Text was added in the interim meeting, will be in d0.5, sub-clause 11.3.4 (JPKG, 29 June 2001)

4.3 Maximum receiver input level

A compliant receiver shall be able to receive a -10 dBm signal at the error rate criterion.

Text added to sub-clause 11.5.x in d0.5 (JPKG, 5 July 2001)

4.4 Regulatory items

Add a 1 MHz RBW to US 15.149 rules

Text added at interim meeting (JPKG, 29 June 2001)

Noticed that Japan is 10 mW limit, so if we want a “world radio” the transmit power would need to be below this.

4.5 OperationalRateSet (added at Portland)

The OperationalRateSet is the set of rates that a device must support to join a piconet. Currently, for the 2.4 GHz PHY, this consists of one rate, the 22 Mb/s QPSK mode.

However, for future PHYs, we may want this, or do we?

Consensus is to delete this parameter and the PiconetBasicRateSet